At Waurika, no such bias existed. Waurika data was evenly distributed in distance, from zero to 30 miles. However, Waurika data had no flight path in the (panel) antenna backlobes, so it over-represented the probability of interference compared to a flight path passing behind asymmetrically arranged sectors of some real-world sectorized sites. Random flight paths would place aircraft in the main beam of any given panel only about 1/3 of the time. This test was conducted radially inward, along the main beam. Thus, the data presented here emphasizes worst case potential for interference.

Histograms of received signal strength summary data from the 1997 test are presented in Figure 6.2 through Figure 6.13. As noted previously, the received signal strength of the AirCell signal is often in the noise floor.

(Note that run 'Q' was omitted from the figures, as no run with a sequence designator "Q" was made)

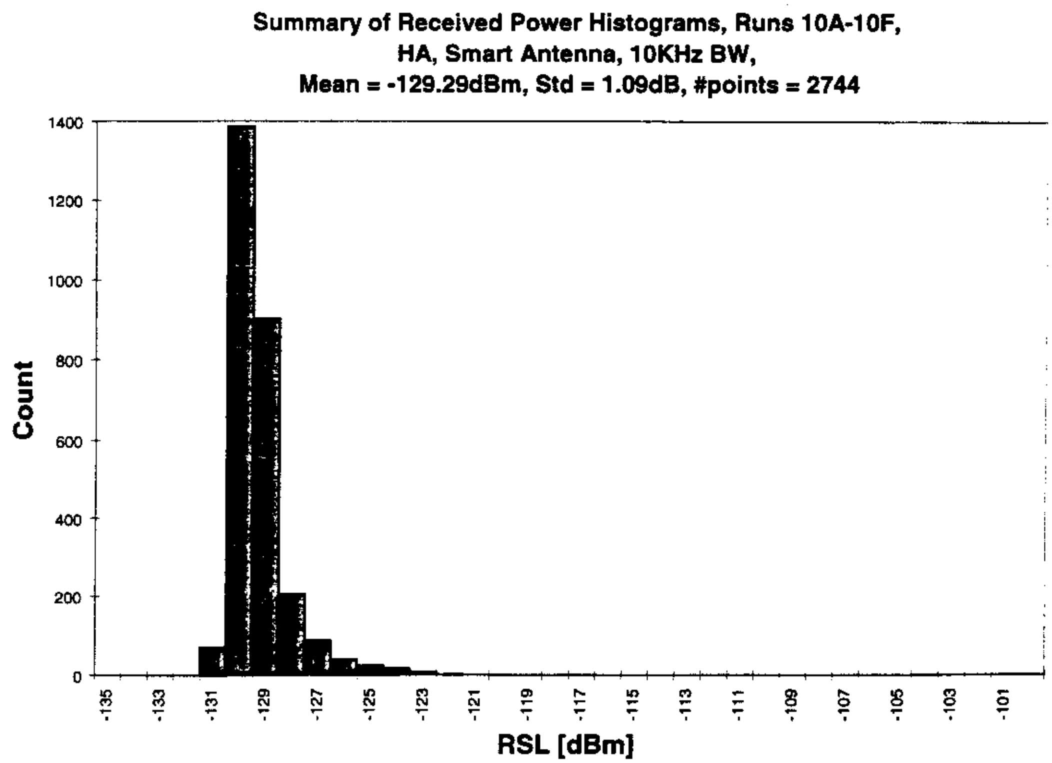

Figure 6.2 Summary histogram, Runs 10A-10F, 10 kHz BW

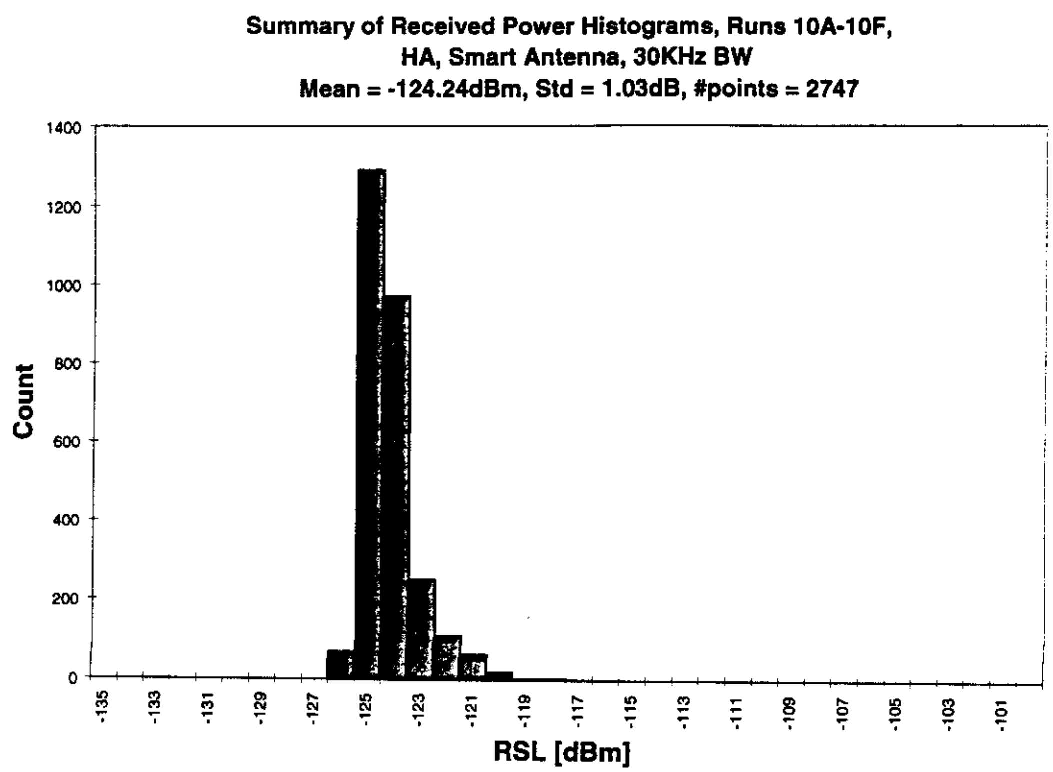

Figure 6.3 Summary histogram, Runs 10A-10F, 30 kHz BW

Summary Received Power Histograms, Runs 10G-10L,
HA, Omni, 10KHz BW,
Mean = -128.56, Std = 2.13dB, #points = 2399

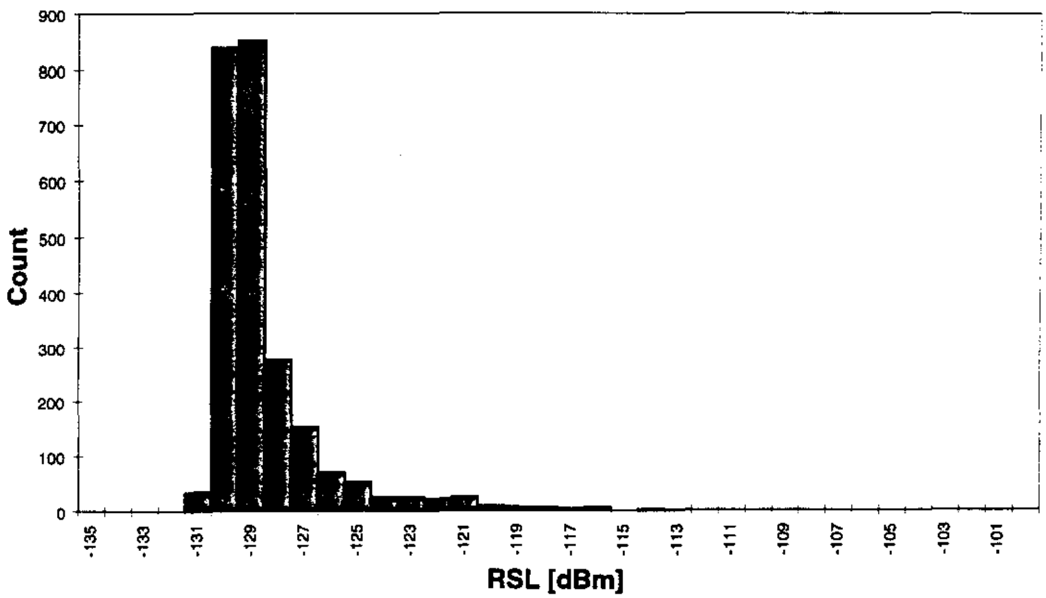

Figure 6.4 Summary histogram, Runs 10G-10L, 10 kHz BW

Summary of Received Power Histograms, Runs 10G-10L,
HA, Omni, 30KHz BW,
Mean = -123dBm, Std = 1.52dB, #points = 2397

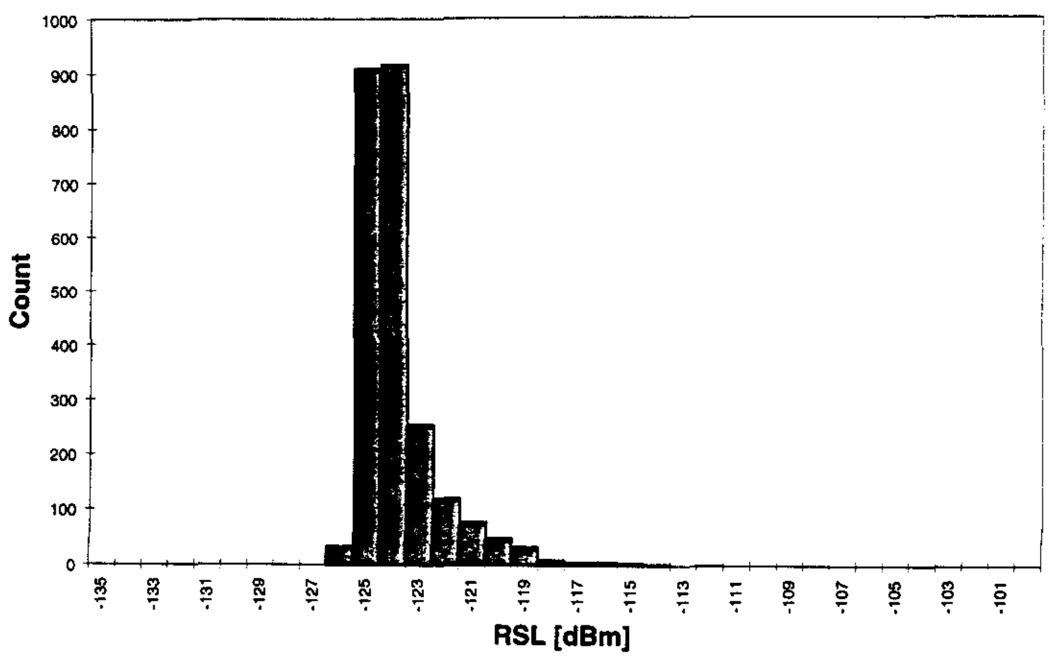

Figure 6.5 Summary histogram, Runs 10G-10L, 30 kHz BW

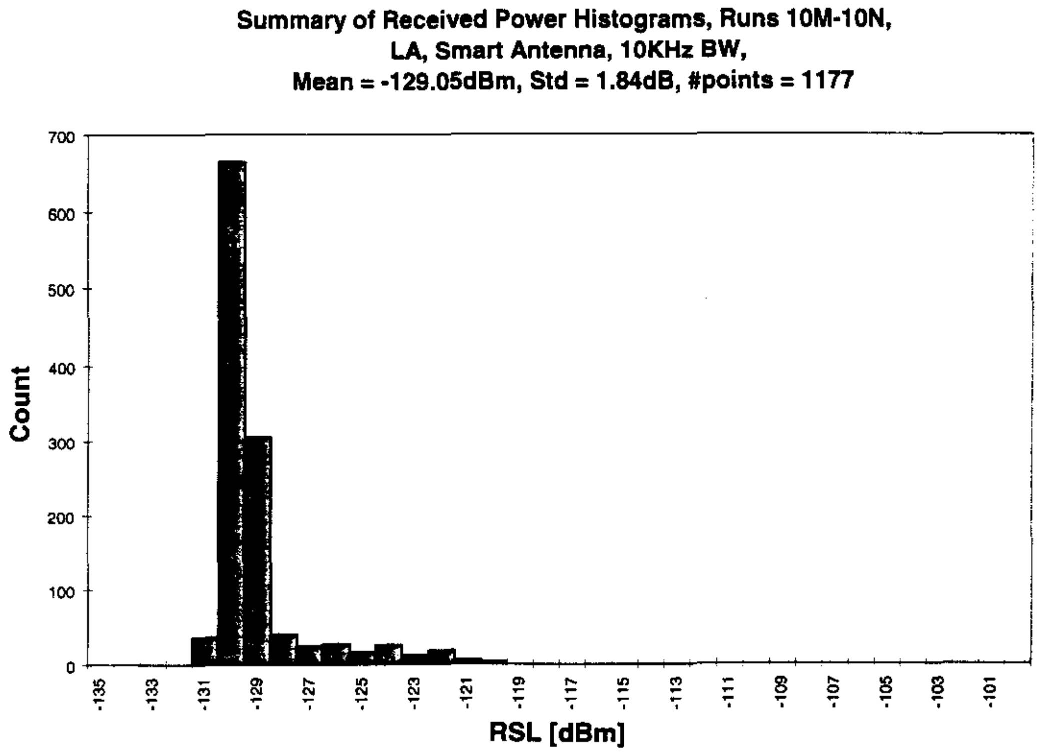

Figure 6.6 Summary histogram, Runs 10M-10N, 10 kHz BW

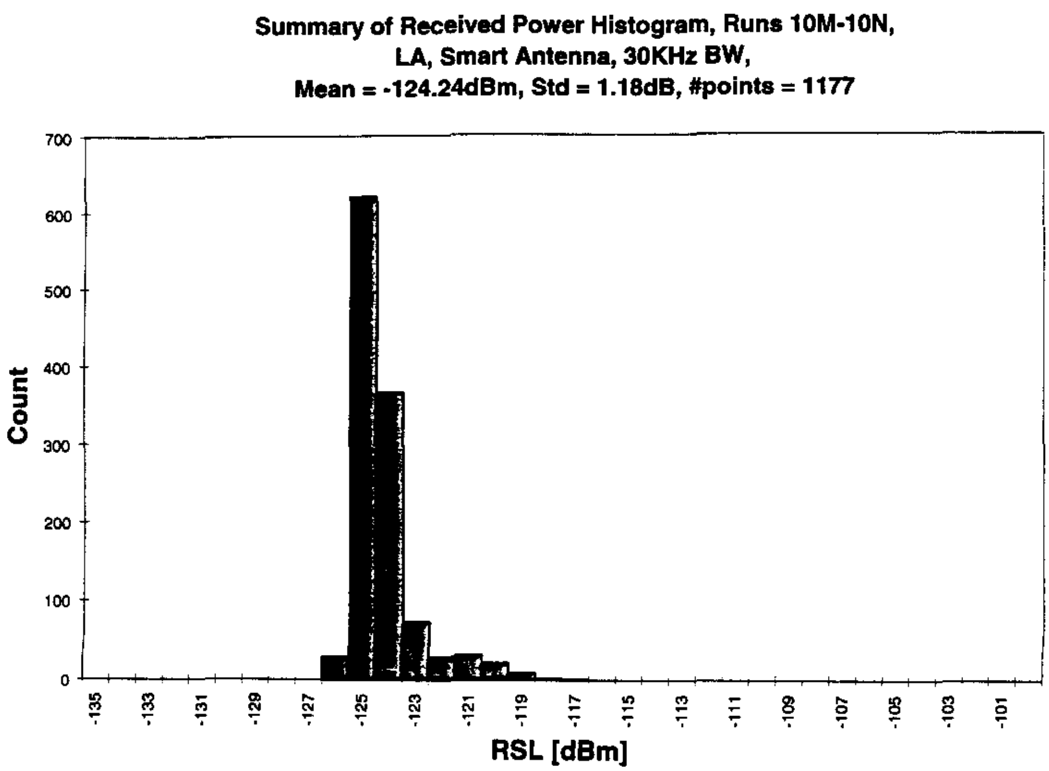

Figure 6.7 Summary histogram, Runs 10M-10N, 30 kHz BW

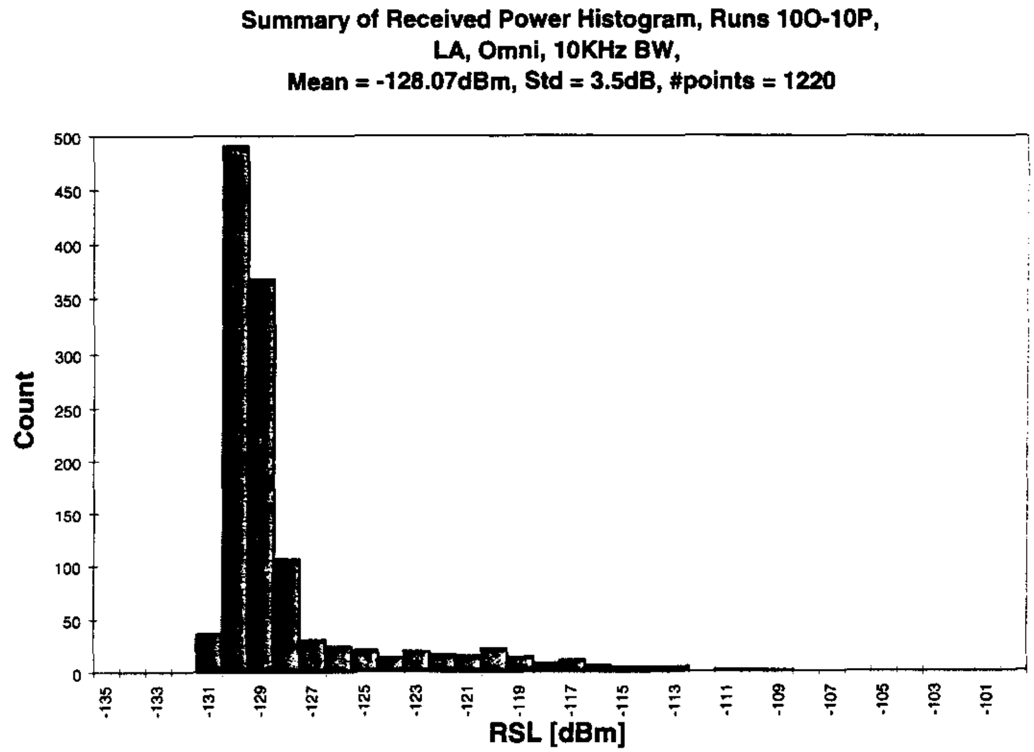

Figure 6.8 Summary histogram, Runs 10O-10P, 10 kHz BW

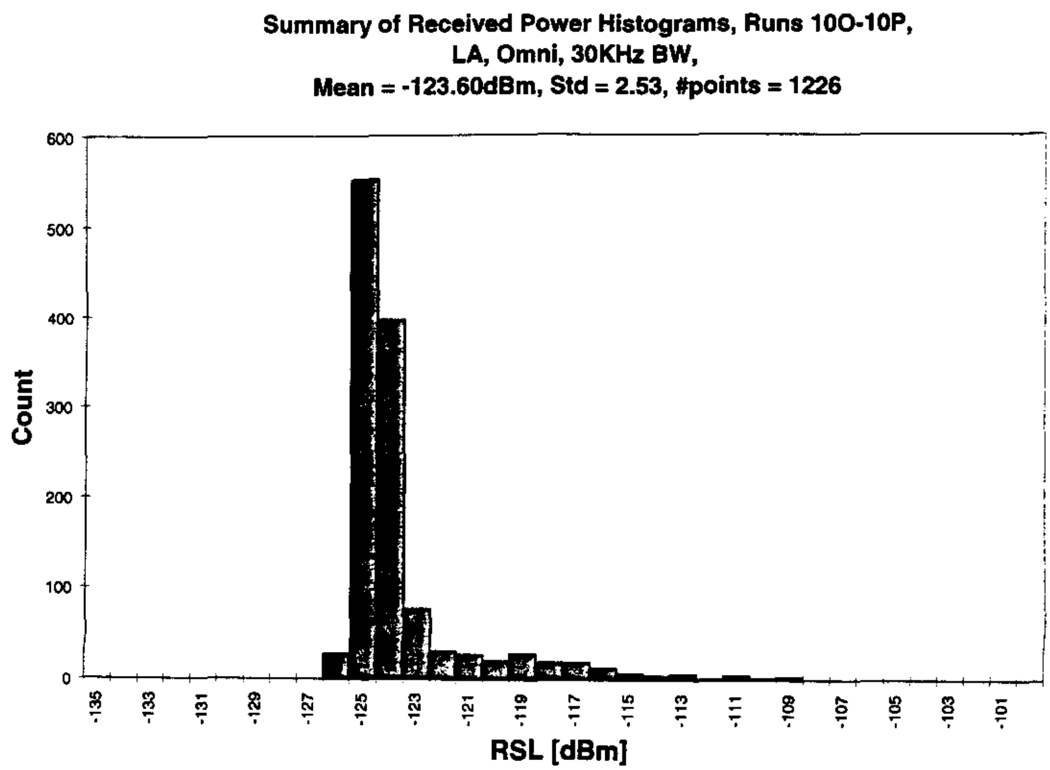

Figure 6.9 Summary histogram, Runs 10O-10P, 30 kHz BW

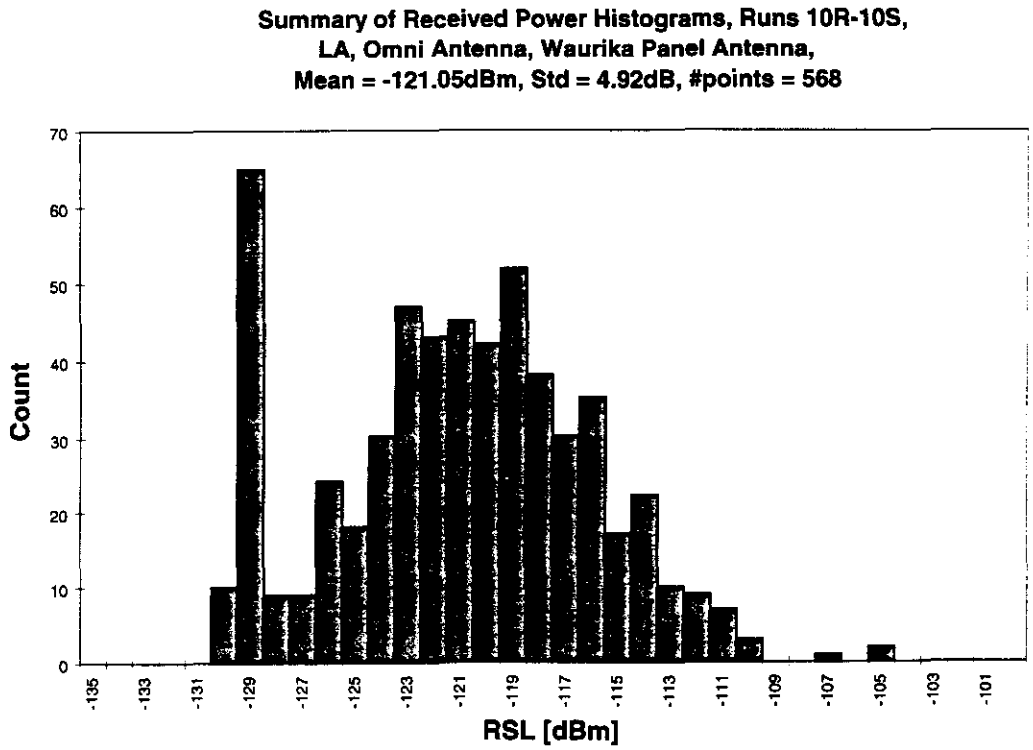

Figure 6.10 Summary histogram, Runs 10R-10S

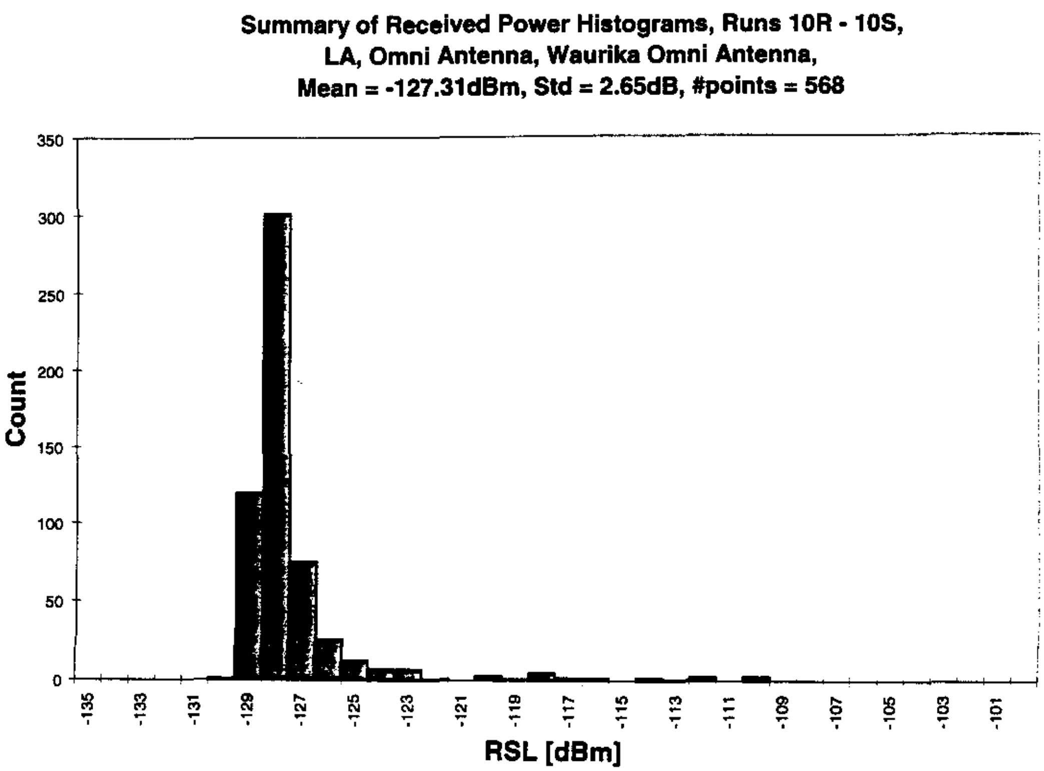

Figure 6.11 Summary histogram, Runs 10R-10S

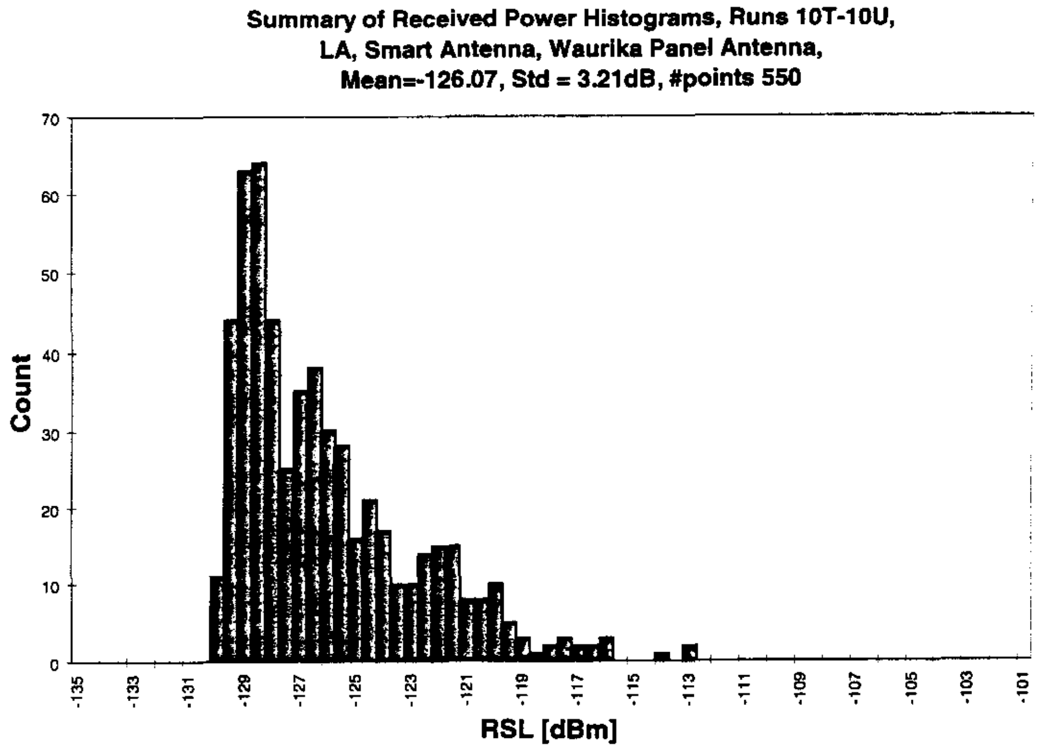

Figure 6.12 Summary histogram, Runs 10T-10U

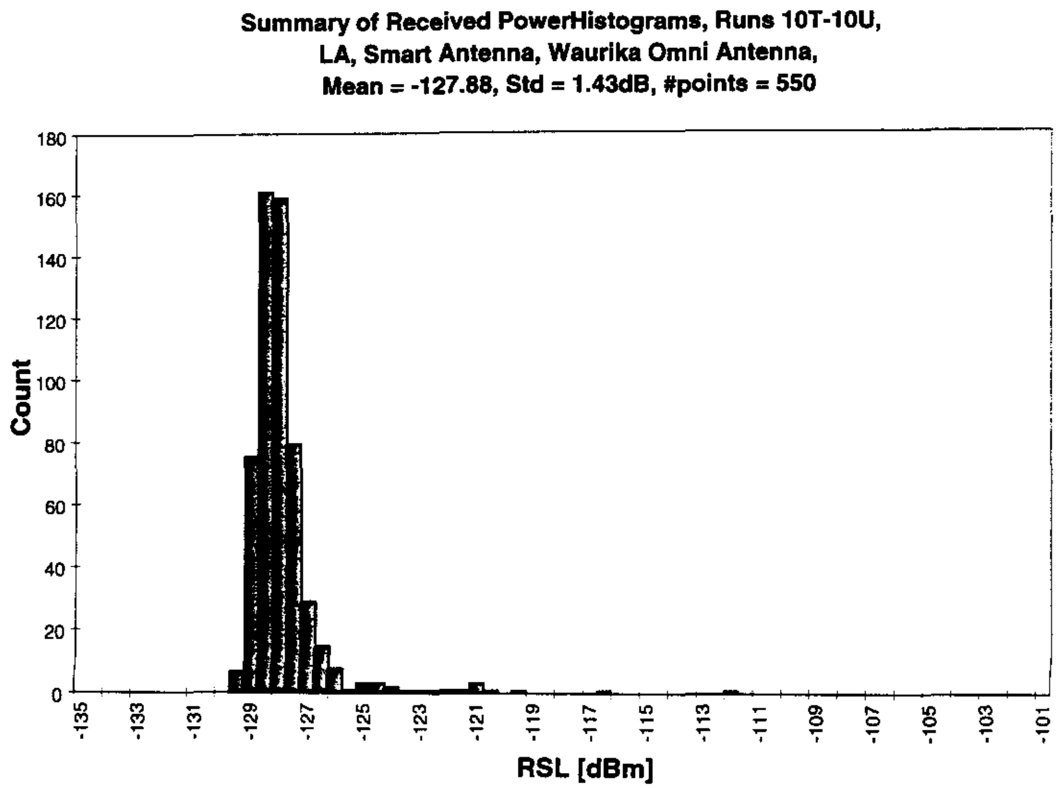

Figure 6.13 Summary histogram, Runs 10T-10U

6.3 Interference Assessment

It is clear that operating point impacts have no practical consequence unless the subscriber unit is operating at or near the maximum +23 dBm transmitter output...because CDMA systems actively respond to interference by adjusting transmitter power (in 1 dB steps), canceling the interference effect. CDMA systems *must do so,* because they must overcome their own self-interference from their own co-channel calls in normal operation. Thus this adjustment, or 'operating point impact' can only manifest as a degraded call if it would 'push' a subscriber unit past the +23 dBm maximum transmit power, where an actual E_b/N_o decrease would take place.

If an impact can't be *subjectively* observed, it is unreasonable to consider it to be 'harmful interference', defined by the FCC as "any radiation or any induction which endangers the functioning of a radionavigation service or of a safety service or obstructs or repeatedly interrupts a radio service operating in accordance with the Table of Frequency Allocations and other provisions..." "Obstructs or repeatedly interrupts" would appear to be the key phrase in this case. It would appear that operating point impacts of 2 dB or less are extremely unlikely to meet this criterion, and that impacts of 1 dB or less *cannot* be considered "harmful interference" per this definition by a reasonable and prudent observer.

6.3.1 Impact probability during co-channel pass by three AirCell subscribers

Thus, the conclusion arises that a 0.5-2 dB operating point impact is the most stringent range of criteria one can reasonably use as a threshold for *observable* interference in the field (using *any* means). Based on the calculation method presented in section 3.2.2, this means that a CDMA system can tolerate *three* AMPS interferers (spaced 21 channels apart, as in Figure 2.5) at the following levels (at the reference point) before the indicated impact takes place:

Rural conditions:	-114.9 dBm for 0.5 dB impact	-108.1 dBm for 2 dB impact
Suburban conditions:	-111.9 dBm for 0.5 dB impact	-105.1 dBm for 2 dB impact
Urban Conditions:	-103.9 dBm for 0.5 dB impact	-97.1 dBm for 2 dB impact
Dense Urban conditions:	-96.9 dBm for 0.5 dB impact	-90.1 dBm for 2 dB impact

<u>Examining Table 6.1 through Table 6.3, one can observe that the average power from AirCell signals don't exceed -123.3 dBm during high altitude passes on an observer site, so there is little or no reason to expect observable, much less 'harmful' interference... There is better than 10 dB of margin, even for the rural case.</u> The same is true of low altitude operations, for vertically polarized observer antennas.

(It is also appropriate to note that '0.5 dB' and '2 dB' impact cases discussed repeatedly herein refer to the impact levels *calculated a priori.* The *actual test results* in the rural case for instance, were a maximum of 0.38 dB and 1.8 dB, respectively. Thus, whenever the rural '2 dB impact case' is discussed, it is in itself an overstatement of the impact observed during testing. Refer to Table 5.1 for the *actual* levels observed for each 'impact case' and CDMA traffic loading.)

At the Waurika observer site, a horizontal polarization panel antenna was also tested. (It was actually dual polarized, but only the horizontal output was measured.) If a terrestrial CDMA site uses polarization diversity on receive, it will select the best (most readable) CDMA signal in any case, but even the horizontal polarized output from the antenna should not exceed an average AMPS power of -120.8 dBm, based on the Waurika data in Table 6.3. These antennas are *not* typically encountered in rural cellular sites. They are typically used at higher traffic, sectorized sites in zoning-sensitive areas where antenna *count* must be minimized and polarization offers the only practical receive diversity option. In other words, polarization diversity antennas are sometimes found in suburban areas, but most often in urban or dense urban areas.

Thus, the horizontally polarized panel antenna data from Waurika should be evaluated in the Suburban, Urban, and Dense Urban contexts *only*, and is *not* applicable to rural environments.

To apply a more stringent criteria than average power during an aircraft pass, one can consider the histograms shown in Figure 6.2 through Figure 6.13. A summary of the impact results is shown in Table 6.4 below:

Table 6.4 Impact probability based on 1997 flight test histograms, three AMPS interferers; Pure Signal Comparison Only, No Situational Probability

Run Numbers	Altitude	AirCell Serving Cell RX Ant.	Receive Polarization	10kHz BW Impact 0.5 dB	30 kHz BW Impact 0.5 dB	10kHz BW Impact 2 dB	30 kHz BW Impact 2 dB
10A-10F	High	Smart	Vertical	0	0	0	0
10G-10L	High	Omni	Vertical	$1.3x10^{-3}$	$3.8x10^{-3}$	0	0
10M-10N	Low	Smart	Vertical	0	0	0	0
10O-10P	Low	Omni	Vertical	0.016	0.022	0	0
10R-10S	Low	Omni	Horizontal*	0.039	-	$3.5x10^{-3}$	-
10R-10S	Low	Omni	Vertical	0.016	-	0	-
10T-10U	Low	Smart	Horizontal*	0	-	0	-
10T-10U	Low	Smart	Vertical	$1.8x10^{-3}$	-	0	-

*Horizontal polarization data is referenced to Suburban operating impact thresholds.
All others are referenced to the rural case.
(Note: the sample interval for 1997 data was 2 seconds.)

The entries in Table 6.4 represent the probability of reaching the indicated operating point impact *during any given 2 second period* of a conversation while:

1) Three AirCell subscribers are airborne and placing calls simultaneously,
2) The AirCell voice channels are all co-channel with the ground CDMA channel,
3) The CDMA co-channel ground cellular channel is carrying one call,
(There is no CDMA system generated self interference to reduce the operating point impact)
4) The AirCell subscriber aircraft all pass near or overhead the observer ground cell at the same time while near an AirCell cell boundary (≥70 miles from the AirCell serving site.)

This combinations of conditions is needed for the impact to manifest at levels as high as calculated. If CDMA traffic loading is greater than one call, or if fewer than three AirCell subscribers are transmitting, the impact will be less.

Even in the low probability event that ***all* these conditions are met**, one can conclude that:

- In areas served by AirCell sites using 'smart antennas', the 2 dB impact probability is effectively nil, *regardless of aircraft altitude or observer polarization.*
- In areas served by AirCell sites using omni antennas for reception with aircraft at high altitude the probability of 2 dB impact is nil.
- In areas served by AirCell sites using omni antennas for reception, with aircraft at low altitude, *regardless of the polarization of the ground CDMA receive antenna* the probability of 2 dB impact is between zero to 0.35% at a given moment (the probability is nil if no horizontal polarization receive antenna is used on the ground).

6.3.2 Impact probability during co-channel pass by one AirCell subscriber

The test was conducted using three AMPS interferers, but it is substantially more likely that *one* AirCell subscriber at a time would be near enough to an observer site to influence its operation. If one assumes that a single AirCell subscriber is present instead of three, one can conclude from the reasoning in section 3.2 that it would have to be received at three times the power level to create essentially the same operating point impact as that measured during the test using three AMPS signals. This is an offset of 4.77 dB.

Rural conditions:	-110.1 dBm for 0.5 dB impact	-103.3 dBm for 2 dB impact
Suburban conditions:	-107.1 dBm for 0.5 dB impact	-100.3 dBm for 2 dB impact
Urban Conditions:	-99.1 dBm for 0.5 dB impact	-92.3 dBm for 2 dB impact
Dense Urban conditions:	-92.1 dBm for 0.5 dB impact	-85.3 dBm for 2 dB impact

Using these levels, one can again consider the histograms shown in Figure 6.2 through Figure 6.13. A summary of the impact results is shown in Table 6.5 below:

Table 6.5 Impact probability based on 1997 flight test histograms, one AMPS interferer; Pure Signal Comparison Only, No Situational Probability

Run Numbers	Altitude	AirCell Serving Cell RX Ant.	Receive Polarization	10kHz BW Impact 0.5 dB	30 kHz BW Impact 0.5 dB	10kHz BW Impact 2 dB	30 kHz BW Impact 2 dB
10A-10F	High	Smart	Vertical	0	0	0	0
10G-10L	High	Omni	Vertical	0	0	0	0
10M-10N	Low	Smart	Vertical	0	0	0	0
10O-10P	Low	Omni	Vertical	2.5×10^{-3}	4.1×10^{-3}	0	0
10R-10S	Low	Omni	Horizontal*	5.3×10^{-3}	-	0	-
10R-10S	Low	Omni	Vertical	5.3×10^{-3}	-	0	-
10T-10U	Low	Smart	Horizontal*	0	-	0	-
10T-10U	Low	Smart	Vertical	0	-	0	-

*Horizontal polarization data is referenced to Suburban 2 dB operating impact thresholds.
All others are referenced to the rural case.
(Note: the sample interval for 1997 data was 2 seconds.)

Thus, for the case of a single AMPS interferer, an operating point impact of 0.5 dB would manifest with probability zero to 0.53% in any two second interval *during a co-channel aircraft pass,* but the impact would not reach 2 dB *regardless of altitude, polarization, or AirCell serving site configuration.*

These interference events are only possible when all the conditions for impact to manifest *are* met;
1) An AirCell subscriber is airborne and placing a call,
2) The AirCell voice channel is co-channel with the ground CDMA channel,
3) The CDMA co-channel ground cellular channel is carrying <u>one</u> call,
(There is no CDMA system generated self interference to reduce the operating point impact)
4) The AirCell subscriber aircraft passes near or overhead the observer ground cell while near an AirCell cell boundary (≥70 miles from the AirCell serving site.)
5) In the case of the (horizontally polarized) panel antenna, the aircraft must be in the main beam of the antenna for interference to manifest. For a typical sector antenna these odds are less than 50/50, however *this factor is ignored* herein.

6.3.3 Impact probability weighting for expected AirCell traffic

To be thorough, one can address the probability of these impact-enabling conditions taking place, and determine how to weight the worst case impacts shown in the previous figures and tables, to obtain more 'real world' expectations regarding the potential impact.

Based upon AirCell growth projections, they expect to carry a nationwide traffic load of about 200 Erlangs. The Continental United States covers about 3,787,319 square miles. Thus one can calculate a call density of 5.3 x 10^{-5} Erlangs per square mile. Some parts of the United States are more populous than others, and some areas are fairly high traffic corridors. No hard data yet exists where areas of AirCell usage will be concentrated. *To be conservative, one can assume that some areas will exhibit a caller density 10 times higher than average.* This yields 5.3 x 10^{-4} Erlangs per square mile.

The 1997 flight test data indicates the strongest AMPS signal levels (those most likely to create an impact) manifest only within approximately 5-10 miles. One can assume for convenience that interference can manifest anywhere within a 10 mile radius. Thus, each cell site can be estimated to have a 314 square mile area in which a passing aircraft *could* create an impact.

Using these assumptions, it is possible to calculate the probability that three or more subscribers are transmitting within 10 miles of a given observer site at a given moment:

The probability a given subscriber is within 10 mi. of a cell: $P_{in} = 314.159 / 3{,}787{,}319 = 8.295 \times 10^{-5}$

Using the Binomial distribution, defined as: $B(p,n,k) := C(n,k) \cdot p^k \cdot (1-p)^{n-k}$

The probability that three or more subscribers of the 200 transmitting nationwide are within 10 miles of an observer cell is:

$$1 - \left(B\left(P_{in}, 200, 0\right) + B\left(P_{in}, 200, 1\right) + B\left(P_{in}, 200, 2\right)\right) = 7.405 \cdot 10^{-7}$$

If a given area is assumed to have 10 times the average traffic density, one can calculate the same way, substituting 2000 transmitting subscribers nationwide:

$$1 - \left(B\left(P_{in}, 2000, 0\right) + B\left(P_{in}, 2000, 1\right) + B\left(P_{in}, 2000, 2\right)\right) = 6.714 \cdot 10^{-4}$$

Thus, if one assumes ten times the estimated traffic density (the '2000 Erlang' case) and a 10 mile radius for aircraft impact, the expected co-channel probability of impact based on Table 6.4 (the three carrier case, having lower impact thresholds) becomes Table 6.6:

Table 6.6 Co-channel impact expectations based on 1997 flight test histograms; including situational probability for presence of 3 airborne interferers

Run Numbers	Altitude	AirCell Serving Cell RX Ant.	Receive Polarization	10kHz BW Impact 0.5 dB	30 kHz BW Impact 0.5 dB	10kHz BW Impact 2 dB	30 kHz BW Impact 2 dB
10A-10F	High	Smart	Vertical	0	0	0	0
10G-10L	High	Omni	Vertical	8.7×10^{-7}	2.6×10^{-6}	0	0
10M-10N	Low	Smart	Vertical	0	0	0	0
10O-10P	Low	Omni	Vertical	1.1×10^{-5}	1.5×10^{-5}	0	0
10R-10S	Low	Omni	Horizontal*	2.6×10^{-5}	-	2.3×10^{-6}	-
10R-10S	Low	Omni	Vertical	1.1×10^{-5}	-	0	-
10T-10U	Low	Smart	Horizontal*	0	-	0	-
10T-10U	Low	Smart	Vertical	1.2×10^{-6}	-	0	-

*Horizontal polarization data is referenced to Suburban 2 dB operating impact thresholds.
All others are referenced to the rural case.
(Note: the sample interval for 1997 data was 2 seconds.)

6.3.4 Impact weighting by probability of co-channel operation

The above table assumes that *all AirCell channels in a region are co-channel with CDMA operations.* Clearly, this is a 'worst case assumption' which overpredicts interference impact, because CDMA operations are *not* always co-channel with AirCell AMPS operation.

Each cellular carrier is allocated 416 AMPS channels. Of the 416 AMPS channels available to a carrier, 21 are AMPS control channels and 395 remain as voice channels. A CDMA channel occupies 41 AMPS channels. There is a (41/395) = 10.4 % probability that any given, randomly selected AMPS channel is co-channel to a CDMA caller. NOTE: For the purpose of calculation herein, it is assumed that if the first AirCell call considered is co-channel, *then all three aircraft in the area are... If the three aircraft channels are assumed to be chosen as independent events, the probability is about 0.01 % - two orders of magnitude lower!*

In some areas multiple CDMA carriers are in use to serve heavy traffic loads, but a CDMA caller can occupy only one such channel at a time, so this does not change the probability that a CDMA caller will be co-channel to a given AMPS channel.

Based upon this reasoning, one can recalculate the probability of impact as follows:

- Weight the CDMA carrier as 10.4% probability of being co-channel to a given aircraft
- Assume 6.7×10^{-4} probability that three subscribers are present and transmitting, as in section 6.3.3
- Use the three AMPS interferer case, which leads to lower (more stringent) impact thresholds

Using these assumptions, the impact probability at any given moment *during peak traffic periods (200 Erlangs, times a factor of ten added on the assumption of a high traffic corridor)* would be:

Table 6.7 Impact probability based on 1997 flight test histograms, three AMPS interferers including situational probability for presence of 3 co-channel airborne interferers

Run Numbers	Altitude	AirCell Serving Cell RX Ant.	Receive Polarization	10kHz BW Impact 0.5 dB	30 kHz BW Impact 0.5 dB	10kHz BW Impact 2 dB	30 kHz BW Impact 2 dB
10A-10F	High	Smart	Vertical	0	0	0	0
10G-10L	High	Omni	Vertical	$9.0x10^{-8}$	$2.7x10^{-7}$	0	0
10M-10N	Low	Smart	Vertical	0	0	0	0
10O-10P	Low	Omni	Vertical	$1.1x10^{-6}$	$1.6x10^{-6}$	0	0
10R-10S	Low	Omni	Horizontal	$2.7x10^{-6}$	-	$2.4x10^{-7}$	-
10R-10S	Low	Omni	Vertical	$1.1x10^{-6}$	-	0	-
10T-10U	Low	Smart	Horizontal	0	-	0	-
10T-10U	Low	Smart	Vertical	$1.2x10^{-7}$	-	0	-

(Note: the sample interval for 1997 data was 2 seconds.)

The probability of reaching 0.5 dB impact is between zero and $2.7x10^{-6}$ during any 2 second period of a typical terrestrial CDMA call, regardless of aircraft altitude, terrestrial CDMA site polarization, or AirCell serving site antenna configuration.

When AirCell subscribers are operating at high altitude, the probability of reaching a 2 dB impact is zero, unless the CDMA site uses horizontal receive polarization; then the probability is less than one in a million during any 2 second period of a typical CDMA call.

Remember that a even a 2 dB impact is unlikely in the extreme to be subjectively observable by a subscriber unless his phone is at or very near maximum transmit power at that moment, and even a brief (2 second) dropout in a terrestrial cellular conversation that takes place on average once every 8½ days of a continuous conversation cannot be characterized as harmful interference which "obstructs or repeatedly interrupts" a cellular conversation. Total blanking (dropouts) in terrestrial digital cellular conversations are far more common than this, and the worst-case AirCell contribution would pass completely unnoticed.

Clearly, to a reasonable and prudent observer, any impact to terrestrial CDMA operations due to AirCell operations is extremely unlikely to be perceived in any way by CDMA users on the ground, especially against the backdrop of normal dropouts and path fades.

7 Conclusions

The reader is urged to carefully evaluate both the body of data and the analysis presented herein. Throughout this report, simplifying assumptions and lines of reasoning have been presented, and the reader should note the consequences of those assumptions; the assumptions made were chosen in such a way as *not* to unduly aid the AirCell case or minimize the interference potential. Rather, they were chosen to be neutral or overestimate the potential for interference impact...
In other words, this presentation is pessimistic from the AirCell standpoint, overestimating the potential for interference impact wherever simplifying assumptions had to be made.

These pessimistic assumptions included: multiplying AirCell traffic projections by a factor of 10, the implicit assumption that a brief 2 dB operating point impact to terrestrial caller will result in a potentially observable event (which it can't unless the subscriber transmit power is *already* at maximum), the assumption that a CDMA subscriber at or near maximum power is *not* in soft handoff (when a subscriber near a cell boundary *should* be), the assumption that the AirCell subscribers are near the fringes of an AirCell serving cell and therefore transmitting at higher than average power, and the *highly* unlikely assumption that AirCell traffic is at its peak while the terrestrial CDMA site is carrying only *one* call on the CDMA channel. A more detailed list of conditions and assumptions is presented in Table 1.1, but it *is* important to note that it is probable that they led to at least one to two orders of magnitude overestimation of AirCell interference potential herein.

Other arguments which could have been helpful to AirCell were simply omitted. For instance, CDMA systems typically utilize soft handoff to improve performance in 1/3 to 1/2 of *all* calls at any moment. Geometric considerations would often place an AirCell subscriber in the backlobes of at least one of the sectorized sites carrying a given CDMA call in handoff, so AirCell influence *would not exist* for that serving site. Many terrestrial systems also utilize downtilt which would lower susceptibility to airborne signal sources. Further, CDMA 'RAKE' receivers utilizing coherent diversity antenna combining would likely 'tune out' interference sources that are off-axis from the CDMA signal of interest, or that have differing multipath characteristics.
In short, the CDMA system is more robust than this experiment and report gave it credit for.

In spite of this unfavorable treatment, the AirCell influence was found to be ***far*** less than the typical design assumption of 3 dB operating point impact from self generated interference in a traffic-loaded terrestrial CDMA system. Further, an AirCell signal is a 'static' influence while self generated CDMA interference is a reactive, positive feedback system as CDMA traffic increases. An AirCell signal becomes proportionately smaller as CDMA traffic load increases... In other words, AirCell impact *drops* as CDMA traffic load approaches typical design levels. This renders potential arguments that an AirCell impact could reduce CDMA system capacity invalid. Likewise, the AirCell influence is so small that it will be masked by typical terrestrial fading statistics (*especially* in a traffic-loaded CDMA system), so a reasonable and prudent observer *cannot* conclude that nominal CDMA cell radius would be reduced. There is no information to support *any* subjectively observable impact to a typical CDMA caller; based on the data, neither call quality, range, nor capacity will suffer.

Based on reasoning presented earlier in this report, it was found that a 0.5-2 dB operating point impact is the most stringent range of criteria one can reasonably use as a threshold for *observable* interference in the field (using *any* means - including sensitive test equipment). Based on the calculation method presented in section 3.2.2, this means that a CDMA system can tolerate *three* AMPS interferers (spaced 21 channels apart, as in) at the following levels (at the reference point) before the indicated impact takes place:

Rural conditions:	-114.9 dBm for 0.5 dB impact	-108.1 dBm for 2 dB impact
Suburban conditions:	-111.9 dBm for 0.5 dB impact	-105.1 dBm for 2 dB impact
Urban Conditions:	-103.9 dBm for 0.5 dB impact	-97.1 dBm for 2 dB impact
Dense Urban conditions:	-96.9 dBm for 0.5 dB impact	-90.1 dBm for 2 dB impact

Examining Table 6.1 through Table 6.3, one can observe that the average power from AirCell signals don't exceed -123.3 dBm during high altitude passes on an observer site, so there is little or no reason to expect observable, much less 'harmful' interference... There is better than 10 dB of margin, even for the rural case. The same is true of low altitude operations, for vertically polarized observer antennas.

When one considers the situation further, one can estimate the 'real world' probability of an operating point impact during any 2 second period of a typical terrestrial CDMA call.
This estimate neglects factors mentioned above favorable to AirCell, but does include probability estimates for:

1) AirCell traffic density (at 10X the traffic AirCell projects),
2) the probability three aircraft will be in a position to contribute interference to a CDMA cell,
3) the probability that they will be co-channel with the CDMA caller.

The results that follow speak for themselves:

Table 7.1 Impact probability based on 1997 flight test histograms, three AMPS interferers including situational probability for presence of 3 co-channel airborne interferers

Run Numbers	Altitude	AirCell Serving Cell RX Ant.	Receive Polarization	10kHz BW Impact 0.5 dB	30 kHz BW Impact 0.5 dB	10kHz BW Impact 2 dB	30 kHz BW Impact 2 dB
10A-10F	High	Smart	Vertical	0	0	0	0
10G-10L	High	Omni	Vertical	9.0×10^{-8}	2.7×10^{-7}	0	0
10M-10N	Low	Smart	Vertical	0	0	0	0
10O-10P	Low	Omni	Vertical	1.1×10^{-6}	1.6×10^{-6}	0	0
10R-10S	Low	Omni	Horizontal	2.7×10^{-6}	-	2.4×10^{-7}	-
10R-10S	Low	Omni	Vertical	1.1×10^{-6}	-	0	-
10T-10U	Low	Smart	Horizontal	0	-	0	-
10T-10U	Low	Smart	Vertical	1.2×10^{-7}	-	0	-

(Note: the sample interval for 1997 data was 2 seconds.)

The probability of reaching 0.5 dB impact is between zero and 2.7×10^{-6} during any 2 second period of a typical terrestrial CDMA call, regardless of aircraft altitude, terrestrial CDMA site polarization, or AirCell serving site antenna configuration.

Remember, even if these impacts *do* occur, there can be no subjective subscriber observation unless the subscriber unit also happens to have no transmit power left to allow the CDMA system to automatically compensate, which it normally can and will...*and even in such a case, a brief (2 second) dropout in a terrestrial cellular conversation taking place on average once every 8½ days during a continuous CDMA conversation cannot be characterized as harmful interference which "obstructs or repeatedly interrupts" a cellular conversation. Total blanking (dropouts) in terrestrial CDMA cellular conversations are far more common than this, and the AirCell contribution would pass completely unnoticed*

Thus, in our best professional opinion, with proper operational engineering, the AirCell system, carrying a full projected traffic load, *will not* be subjectively observable by typical CDMA subscribers on the ground.

Full scale AirCell operations, properly engineered and deployed, should pass totally unnoticed by terrestrial cellular subscribers, whether they use AMPS (as discussed in a previous report) or IS-95 CDMA, as discussed herein.

Thus, the AirCell impact cannot be characterized by a reasonable and prudent observer as meeting the FCC criteria for "harmful interference" with respect to terrestrial CDMA services in any way. The test data shows no significant probability that AirCell operations constitute "radiation or any induction which endangers the functioning of a radionavigation service or of a safety service or obstructs or repeatedly interrupts a radio service operating in accordance with the Table of Frequency Allocations and other provisions..." The evidence instead indicates that the impact is so small that it probably *cannot be measured at all* in the terrestrial fading environment using commercial subscriber and base station equipment.

Appendix A Calibration Approach and Values

Prior to conducting the test, it was necessary to measure the losses for all RF signal paths, enabling signals and noise to be presented to the cell site and phones at known levels. Path loss measurements were made with an H-P 8594E spectrum analyzer, with the sweep generator option. The analyzer was configured for the appropriate sweep bandwidth and generator power, and two appropriate length test cables were attached to the input and RF out ports. A barrel was inserted between the test cables, and a sweep taken. This trace was then stored, and trace math was performed such that the path was displayed as '0 dB' across the sweep. This canceled any sweep generator level errors and removed the losses due to the test cables. The barrel between the test cables was then removed. The signal path to be measured was then inserted between the test cables, a sweep was taken, and the output printed. The path loss at 836.52 MHz (the center frequency for the CDMA channel used) was considered the loss for reverse channel paths, and the loss value at 881.36 MHz was used for forward paths.

Since every individual measurement taken is subject to some small error, the *number* of measurements on each end-to-end path was minimized. Where possible (subject to spectrum analyzer dynamic range limitations) entire paths were measured end to end, instead of measuring each component individually (which would have had a larger cumulative error). In some cases however, the path was broken into two or more parts, and the path loss measurements were summed to create an end-to-end value.

Figure A.1shows the equipment setup, with designators added to indicate specific measurement points for various paths. Measured path losses are presented in Table A.1.

NOTE: In the table, losses are expressed to 0.01 dB resolution, as displayed by the spectrum analyzer marker function. This implies (within the scientific community) that the 1/100th dB digit is significant. We **do not** intend to imply this. Measurement linearity and repeatability for the spectrum analyzer is on the order of ¼ to ½ dB, and the measurement <u>accuracy</u> is thereby limited. The increased resolution was left in the table for one reason only: that summations of multiple path segments created from this table would not have additional rounding errors introduced by the use of fewer significant figures. Sum, then round as needed.

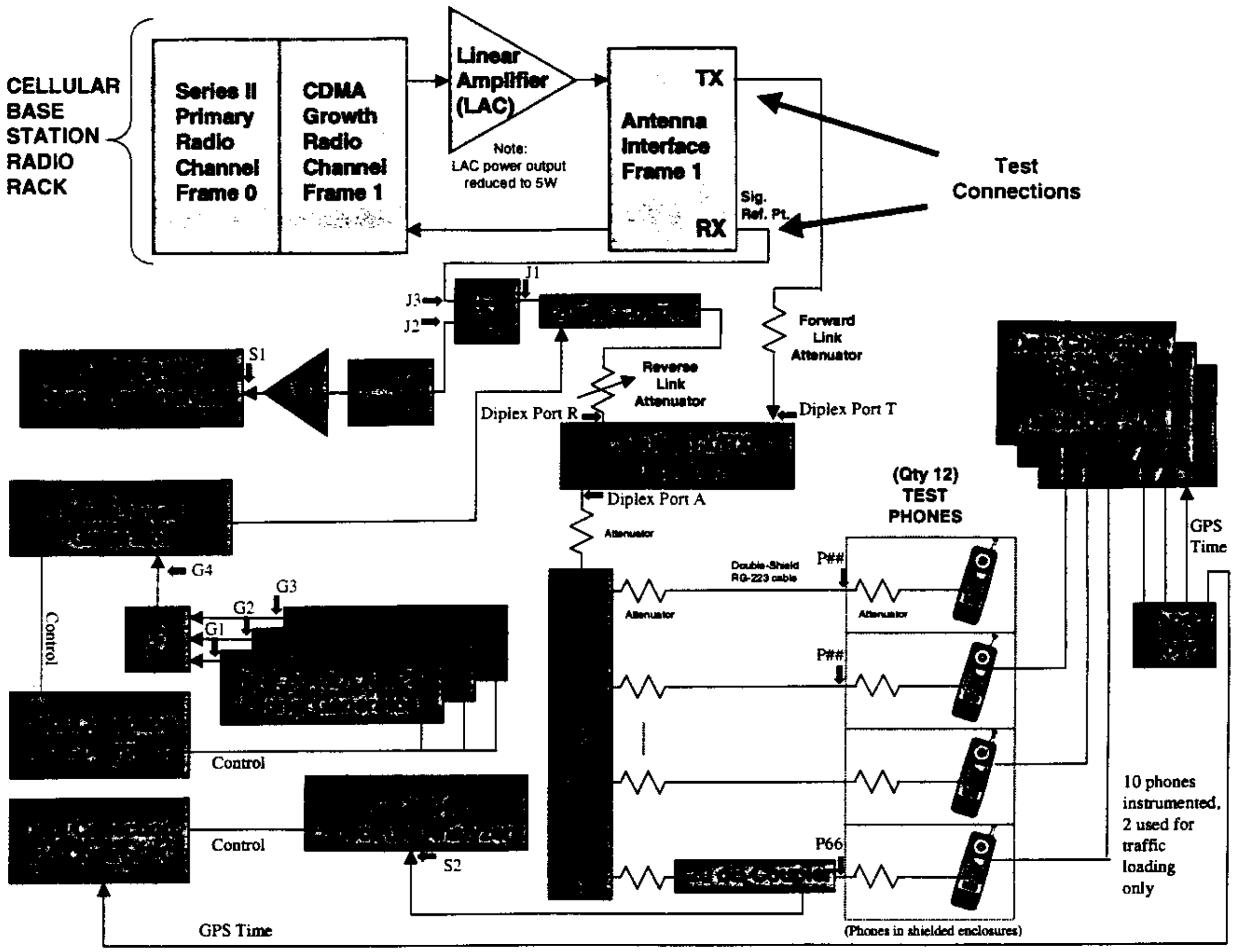

Figure A.1 Test setup with path loss measurement points shown

Table A.1 Test setup path losses

Path (from/to)		Reverse Path Loss (dB)	Forward Path Loss (dB)	Comments
Test Telephone 228-0060 Enclosure feedthrough P60	Diplex Port A	36.91	36.84	
P61	Diplex Port A	36.88	36.84	
P62	Diplex Port A	36.80	36.90	
P63	Diplex Port A	37.06	37.01	
P64	Diplex Port A	36.78	37.06	
P65	Diplex Port A	36.70	36.68	
P66	Diplex Port A	37.04	36.61	Includes 20 dB coupler
P67	Diplex Port A	36.94	36.80	
P68	Diplex Port A	36.69	36.60	
P69	Diplex Port A	36.68	36.82	
P70	Diplex Port A	36.90	36.69	
P71	Diplex Port A	36.40	36.35	
Attenuator in enclosures		40 nom.	40 nom.	Value per mfg. Specification
Diplex Port A	Diplex Port R	0.46	>45	
Diplex Port A	Diplex Port T	>45	0.74	
Diplex Port A	J2	4.61	>45	Rev link Step Atten set to 0 dB
Diplex Port A	J3	4.59	>45	Rev link Step Atten set to 0 dB
White Noise Gen Out	J3	24.40	24.13	
P66	S2	21.31	21.49	
G1	J2	30.64	31.04	
G1	J3	30.62	30.11	
G2	J2	30.57	30.62	
G2	J3	30.66	30.50	
G3	J2	30.72	30.36	
G3	J3	30.42	30.96	
Diplex Port T	T1	25.33	25.50	Incl Fwd Link Atten; Narda Mod #26298 150W, 20 dB pad
J3	Site Sig Ref. Pt.	22.28	22.37	Incl 20' RG214
J2	S1	20.10	40.65	

Note: While path losses are expressed to a ***resolution*** *of 0.01 dB to reduce rounding error when adding signal paths together, measurement* ***accuracy*** *is subject to the linearity and repeatability limits of the H-P 8594E. Measurement accuracies are generally ± ¼-½ dB.*

Table A.1 above shows the calibration values obtained prior to testing. After testing was completed, a post-test calibration was conducted to confirm that the test setup did not evidence any path loss drift beyond typical measurement error, and confirm that no components had failed.

These values were used to calculate the offsets for various pieces of test equipment, so that all levels could be referenced to the site receive antenna input.

Therefore, all reverse channel signal strengths presented herein (unless specifically noted otherwise) are expressed at the 'Sig. Ref. Pt.' in the setup diagrams. This point is the antenna jumper input to the Antenna Interface Frame. Forward Channel path losses are referenced to the TX antenna output connector of the same frame. Forward channel TX power was not a critical variable in this test, but the path attenuation was measured in the same detail as the reverse channel paths.

During the test, a deliberate path imbalance was used in the setup favoring the forward channel, for two reasons:

- The LAC was turned down to only 5 W output, the minimum level at which it would operate in a stable manner. This reduced potential unintentional radiation from the LAC, and the forward path attenuation needed.
- The test was intended to evaluate *reverse channel* impact, so running the forward link a bit 'hot' from the subscriber unit viewpoint assured that forward link FER was low and as path loss was increased, dropped calls resulted from reverse, not forward link failure. In the real world, the forward link is often responsible for call quality problems, and calls may be degraded/dropped through various mechanisms unrelated to the reverse link performance. This was a conservative test approach (not favorable to AirCell), as it placed all call failures on the shoulders of the reverse link.

The forward link was not excessively 'hot' however, and was reported by the phones in the mid -90's (dBm) range, so that access probes by subscriber units were not significantly skewed in power level, nor was the open loop portion of the IS-95 dynamic power control methodology. Once a call was established, the closed loop power control naturally overrode any biases, so there was no effect upon reverse channel transmit levels more than a couple of seconds after call establishment.

Once path calibration was completed, offsets were established between the levels at the various pieces of test equipment and the reference point at the antenna interface frame. The offsets used in setting test equipment were as follows:

H-P 8648D narrowband (AMPS) sources: 52.9 dB higher than desired at the reference point.

PNG 7112 'White' Noise Generator: 46.7 dB higher than desired at the reference point.

Spectrum Analyzer (S1): Readings were 42.4 dB higher than reference point
(Compensated for by setting analyzer 'preamp gain' to 42.4 dB)

Spectrum Analyzer (S2): Readings were 61.3 dB lower than actual '0066' phone transmit power
(Compensated for by setting analyzer 'preamp gain' to -61.3 dB)

Appendix B Test Run Procedures

Prior to beginning testing each day, the system time for all computers (with the exception of the Lucent Autoplex CDMA switch) were synchronized to GPS time, using the GMT time zone. All testing was conducted and logged using this reference time. The SAFCO walkabout data collection computers and the spectrum analyzer logging computer were directly connected to the GPS receiver, and logged this time directly. This provided a common reference for all measurements. The Lucent switch utilized a free running local time reference, which was easily accurate enough to permit time alignment of call trace data with other data sources during postprocessing.

Next, all charging cables were disconnected from test phone enclosures, and the enclosures were verified to be tightly closed, with the subscriber units inside turned on.

Then, an RF call trace was started on the Autoplex switch, with the (fastest possible) update rate set; a two second update period. The duration of the call trace was set to four hours, so multiple runs were carried out during each trace. Two to three call traces per day were typically run, allowing 8-12 hours of testing.

The following steps were then taken for each run:

1. Noise and interference generators were configured in accordance with the selected test conditions, using the control computer, which logged this action.
2. Fixed attenuation values were confirmed to be correct for the run conditions, and the step attenuator was set to zero dB.
3. The spectrum analyzer logging computer was started.
4. The SAFCO walkabout computers were configured to place the specified number of test calls for the run, and started. The operator waited for the computers to dial the phone(s) and place the test calls.
5. After the specified number of test calls were up and all computers began logging, the 'beginning of run' was called, and all configuration data was manually logged in a notebook, along with the time that the run began.
6. After the specified time elapsed (two minutes for each normal data point, and four minutes for thermal-noise-only runs), the step attenuator was advanced 1 dB. The attenuator setting and time of change was manually logged.
7. Step 6 was repeated, increasing path attenuation in 1 dB steps until calls began to drop, and failed to re-establish. (The SAFCO Walkabout computers automatically redialed upon dropping any call.)
8. 'End of run' was called, the time and attenuator value was logged.
9. The SAFCO walkabout computers were then stopped and reconfigured for the next run. The spectrum analyzer logging computer data collection was stopped. The signal generator control computer also logged end of run.

This basic procedure was followed for each run. Logfiles were named by run time or run number, using a consistent naming convention in accordance with the manually-kept log.

A further measure was devised to cross-check the AMPS impact, which was used for the 0.5 dB measurement runs. The test run procedure was changed as follows:

1. Noise and interference generators were configured in accordance with the selected test conditions, using the control computer, which logged this action. *The combined AMPS interference was then removed by disconnecting point "G4" in Figure A.1. This provided a "No AMPS" data point.*
2. Fixed attenuation values were confirmed to be correct for the run conditions, and the step attenuator was set to zero dB.
3. The spectrum analyzer logging computer was started.
4. The SAFCO walkabout computers were configured to place the specified number of test calls for the run, and started. The operator waited for the computers to dial the phone(s) and place the test calls.
5. After the specified number of test calls were up and all computers began logging, the 'beginning of run' was called, and all configuration data was manually logged in a notebook, along with the time that the run began.
6. *After the specified time elapsed (two minutes), the AMPS signals were reconnected to point "G4". (No step attenuator change was made at this time.) The time of change was manually logged.*
7. After the specified time elapsed (two minutes), the step attenuator was advanced 1 dB. The attenuator setting and time of change was manually logged.
8. Step 7 was repeated, increasing path attenuation in 1 dB steps until calls began to drop, and failed to re-establish. (The SAFCO Walkabout computers automatically redialed upon dropping any call.)
9. 'End of run' was called, the time and attenuator value was logged.
10. The SAFCO walkabout computers were then stopped and reconfigured for the next run. The spectrum analyzer logging computer data collection was stopped. The signal generator control computer also logged end of run.

The latter procedure provided an additional data point for each run, the "No AMPS" case, for the minimum path attenuation used in the run. This minimum path attenuation data point was chosen so that reverse channel dynamic power control was still active.
Thus, a direct comparison could be made in postprocessing between this point and the one which immediately followed it (seconds later) using *exactly* the same test conditions *with* AMPS signals present. The difference in reverse channel transmit power between these data points gave a direct measure of AMPS impact which eliminated the impact of long term equipment drift between measurements.

Appendix C Detailed Data Reduction Process

After the experiment was completed, many Gigabytes of data had been produced, and a methodology had to be developed to reduce it to a more usable form. There were several types of files produced during the test:

- The largest quantity of data by far was the SAFCO Walkabout data. It was stored in a proprietary binary format by the SAFCO software, known as ".SD5" files.
  SAFCO OPAS software was utilized to convert the .SD5 data into ASCII format that could be read by other software.

- The Lucent Autoplex RF call trace software produced ASCII output files, but the files were heavily annotated and irregular in format. They are intended to be read by humans, rather than automated tools.
  It was necessary to write software to read, parse, and interpret this data.

- The spectrum analyzer logging software produced data in ASCII format, as described in the 1997 flight test report referenced earlier.
  These files can be manually reviewed, but were not used in automated data reduction.

- The computer controlling noise and interference levels also logged in an easily readable ASCII format.
  These files can be manually reviewed, but were not used in automated data reduction.

- Finally, a comma delimited run logfile was manually written for each individual run. These files describe the run conditions and the begin/end time for each data point taken.
  These files were used as the 'key' for interpreting the data contained in other files.

WSE wrote custom software to reduce the data. The program performs the following functions:

1. It reads the manually-written run logfile, to determine the run conditions and start/end time for each data point in the run.
2. It asks the operator for the time offset (which was manually determined) between the Lucent Autoplex Switch time and GPS time.
3. It reads from 1 to 10 OPAS ASCII output files containing telephone data sampled at 50 samples per second.
4. It averages the 50 data samples per second for each telephone, reducing the data to one sample per second per parameter per phone.
5. It parses the Lucent Autoplex call trace, extracting BER, E_b/N_o, and other information, placing this data in 1 second bins.
6. It determines *how many* phones were in the full-rate Markov conversation mode in each second, comparing this result to the desired number of calls for the run. (12 calls were expected to produce 10 Walkabout-logged files, as the remaining 2 phones were not instrumented.)
7. It time aligns the Lucent Autoplex RF call trace data with the telephone data, merging the data into a single time-aligned output file readable by Excel, "CDMATimeAlignedData.CSV", and writes a reduced set of fields to "CDMAShortData.CSV"

8. It averages data over the duration of a 'data point' (usually 2 minutes) described in the run logfile. This averaging process automatically discards the first and last 10 seconds of each data point processed. (This eliminates transients caused by step attenuator switching, and allows for human response time in making manual step attenuator changes) This averaging process also discards data from periods during which the number of calls up (see #6) does not agree with the required number of calls.
9. It outputs the averaged data points, including E_b/N_o, BER, individual telephone transmit power(s), and average phone transmit power (all phones combined), and test conditions to "Summary.CSV"
10. It writes "CDMATestAnalysis.LOG", a file containing test conditions, data point start/end times as processed, the number of valid samples averaged, errors encountered, etc. (This is a diagnostic file to cross-check that the data reduction executed properly.)

The data reduction procedure was as follows:

- First, the raw ".SD5" files were converted to delimited ASCII format, using the SAFCO OPAS package.
- A series of data directories was built, by data collection day and run number.
- The run logfile was placed into the appropriate run directory.
- The Lucent RF call trace log appropriate to the run was copied into the run directory.
- The SAFCO OPAS-processed phone logfiles were placed into the appropriate run directories.
- The postprocessing program and an Excel data-graphing spreadsheet were copied into each run directory.
- The postprocessing software was run, using an estimate of the time offset between GPS time and the Lucent switch time.
- The resulting "CDMAShortData.CSV" file was copied into the Excel data graphing spreadsheet.
- The spreadsheet was examined for time offset between the call trace data and the phone data.
- The postprocessing program was re-run with a revised time offset (if necessary) and re-examined in Excel to assure the offset was correct.
- The data was cross-checked as necessary.
- The "Summary.CSV" files were renamed by run number, and aggregated into directories by test case; noise level and expected AMPS impact.
- The reverse transmit power operating point impact from each run having a "No AMPS" data point was extracted and noted.
- A MathCAD spreadsheet was written to graphically display the reverse transmit power operating point impact, based upon the difference in phone transmit power between corresponding runs with and without injected AMPS signals. This spreadsheet was run for each test case.

At this point, over 3,600 data files had been created, comprising 25 Gigabytes of data, both raw and reduced. The results were expressed as a series of discrete operating point impact values (for runs having a "No AMPS" data point), a series of Excel run plots showing measured parameters vs. time for each run, and MathCAD spreadsheets showing impact for each test condition... The results that had been sought.

Appendix D. Time Domain Run Results

This appendix presents the time domain plots for each run made during the test. These plots show the time-aligned data in its raw form. Each plot shows the transmit power level of the subscriber unit(s), the average transmit power of all phones in use, the number of calls up at any time, and the RF call trace reports of reverse link FER and E_b/N_o.

Because the CDMA system *did not* have the ability to run multiple simultaneous RF call traces, the FER and E_b/N_o are always for a single phone, designated 228-0066 in the plots. Transmit power for this phone is also set apart as a blue trace, while all other phones are shown in gray. This particular phone was new-in-box when it was obtained for the test. It was bought from Agilent Technologies (formerly SAFCO) from stock. (Agilent stocks some phones for use with their Walkabout cellular testing equipment.) The remaining 11 phones used for testing were an assortment of new and used phones; representative of those typically found in service.

Note in the plots that reverse path loss (attenuation) steps are visible (at least during the first part of the run) as step increases in reverse transmit power accompanied by glitches in FER and E_b/N_o. The nominal step time is usually aligned with major time divisions in each plot.

Below each figure are notations for three conditions affecting the interpretation of the plot;

1) The total reverse link path loss at the *beginning* of the run
2) Whether the first data 'point' interval is 'No EAMPS' or 'EAMPS' Present at start of run (for runs which had injected EAMPS signals)
3) Whether unusual conditions existed, such as operator error which created invalid data points. (In such cases, improper points were removed in postprocessing)

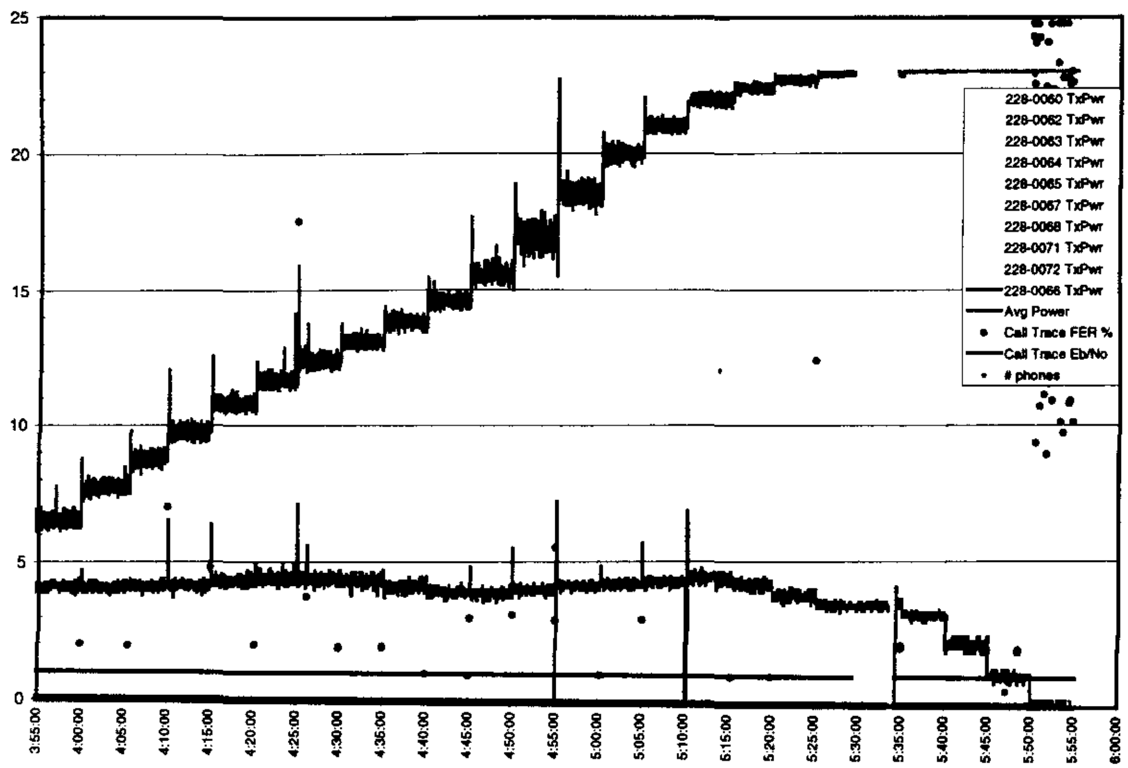

Figure D.1 Time Domain Data, Baseline Thermal Noise Only, 1 call
(Start Atten. 129 dB)